# INTRODUCTION

1. The information in this book is of a general nature and applicable to all forms of Low-angle Director installations. Detailed descriptions of the various mechanisms to which references are made are not given since they already exist in the handbooks in this series which treat with the individual types of gear.

2. In view of the rapidly decreasing number of disturbed-line-of-sight directors, the book is written from the aspect of the modern undisturbed-line-of-sight director with gyro stabilisation of the Layer's and Trainer's line of sight. Reference is occasionally made to the fact that a specific point does not apply to a disturbed-line-of-sight director.

3. The new terms " Level " and " Cross-level " are defined in Chapter II, and are used throughout in the sense in which " Roll " and " Cross-roll " have previously been used.

## CHAPTER I

# THE DIRECTOR SYSTEM

### DEVELOPMENT

5. The conception of a system of Director firing dates from the days of the old three-deckers with broadside guns. Attempts were made to concentrate the fall of shot of the broadside at one point by means of marks on the bearing racers and carriages to which the guns were trained and laid. Sets of marks were made for two different ranges, and the moment at which to fire was ordered by a separate observer, using a telescope which was kept steady by a large pendulum weight. This system, which was invented by a carpenter in 1829, thus had some of the principles of the modern stabilised-director system.

6. Electric firing was introduced in 1870, but the method of concentrating the fire of all guns on the beam at one or two fixed ranges (about 800 to 1000 yards) remained very much the same as it had been for the previous 50 years. As all guns were laid in this way by exact measurements, the shots fell in a reasonably small group, but whether this was anywhere near the target depended entirely on the Captain and the Navigator handling the ship so as to pass the target, when abeam, at the range for which the guns had been laid. As can be imagined, this method was not very well suited to the engagement of a moving target.

The principle of laying guns to fixed marks and then waiting until the sights came on, persisted until the end of the century, although firing ranges had increased very considerably and a number of refinements in the actual methods employed had been made in the interval.

7. The opening years of the twentieth century saw a great advance in naval gunnery under the leadership of three very distinguished officers, Admiral of the Fleet Lord Fisher, Admiral Sir John Jellicoe and Admiral Sir Percy Scott. Under their enthusiastic direction many fire-control instruments were invented by the officers of the various fleets, telescopic sights were fitted to all guns, the ranges at which battle practices were carried out increased by leaps and bounds, and the science of naval gunnery advanced more in fifteen years than it had done in the previous five hundred.

8. The prototype of the modern director system was invented by Admiral Sir Percy Scott during this period and tried out in H.M.S. *Neptune* in 1911. The following year it was improved in design and fitted to the *Thunderer*. This director, which became known as the "Tripod" type, completed successful firing trials in that year and was adopted for fitting in all capital ships. A similar sight is still used in the "Revenge" class battleships.

9. Thus at the outbreak of the war of 1914–1918 the majority of the capital ships of the Grand Fleet were equipped for director fire. The cruisers, however, were not so equipped.

The Battle of the Heligoland Bight was fought in low visibility principally between opposing cruiser forces, and the conditions of the action demonstrated very clearly the difficulty of indicating targets to individual Gunlayers. This difficulty was again emphasised at the Battle of the Falkland Islands even though only two heavy ships were engaged on each side.

At the Battle of Jutland the director system proved itself beyond the shadow of a doubt to be the best method of aiming and firing guns, and it was fitted in all ships down to and including destroyers.

10. The disturbed-line-of-sight directors which were then fitted were nothing more nor less than gunsights mounted high up in the ship, equipped with electrical transmission systems to send gun-elevation and gun-training to receivers at the quarters, and an electric firing pistol connected to the firing circuits of all guns. Since, however, this gave positive target indication to all the individual Gunlayers, and resulted in a salvo fired at a definite moment, instead of, as hitherto, a ragged volley spread over a period, it was an immense improvement on anything that had gone before.

11. The next development took place when the fire-control installations for the ships, built after the war, were designed. In *Nelson* and *Rodney* undisturbed line of sight directors were fitted for the first time, and gyro stabilisation of the Layer's and Trainer's line of sight, combined with gyro control of the instant of firing, was incorporated in the design of the sight. In these sights the setting of range and deflection was added differentially to the elevation and training produced by the director telescopes, instead of by actually offsetting the telescopes and throwing the Layer and Trainer off the point of aim.

All modern director sights are of this type and are mounted in a revolving director control tower which also houses the control personnel.

### PRINCIPLES

12. The essential principle of any director system is that the guns are laid, trained, and fired from one centralised position which can, within reason, be placed in the most favourable place in the ship from the point of view of visibility, freedom from spray, etc.

The director sight, either by itself or in conjunction with other instruments for providing T.E. and deflection, performs the same function as a gunsight mounted high up in the ship. That is to say, the sight measures director training and director elevation, and deflection and tangent elevation are added to them to produce gun-elevation and training. This addition may be made in the D.C.T. or elsewhere.

13. Movement of the director telescopes, or the setting of range and deflection, operates electrical transmitters which control the remote power control (R.P.C.) relays and/or the electrical training and elevation pointers at the guns. In the former case the follow-up by the gun is fully automatic. If no R.P.C. is fitted, the Gunlayer and Trainer follow up the movement of the electrical pointers with pointers driven mechanically by the movement of the gun.

The firing circuits may be closed either by the Director Layer pressing his trigger, or by the closing of a gyro controlled contact at the moment when the Director Layer comes on to his point of aim.

Frequently more than one Director can control each armament, and it is possible by means of a change-over switch to arrange for either Director to control all or part of an armament.

### REASONS FOR THE ADOPTION

14. (*i*) It is a quick, reliable and accurate means of getting all the guns of an armament on to the target and keeping them there.

(*ii*) It enables the ship's fire to be shifted quickly to a fresh target.

(*iii*) It enables the guns to be laid for loading without losing the target.

(*iv*) As the director sight is invariably high up in the ship, the Layer and Trainer are less subject to interference from smoke, spray, shell splashes and noise.

(*v*) A director system can be depended upon to give a smaller spread, especially when an R.P.C. system is fitted to the guns.

(*vi*) The simultaneous fall of shot facilitates spotting, especially when concentrating.

(*vii*) The clear interval between salvos assists the rangetakers and also gives a silent period during which control orders can be passed.

(*viii*) Blind fire can be carried out, controlled to a greater or less extent by the radar sets and fire-control tables.

15–19.

## CHAPTER II

## DEFINITIONS

### GENERAL

20. *Gun Director* consists of telescopes mounted so that they can be moved in training and elevation. The telescopes can thus be made to follow the enemy.

*Director Tower* is the housing for a Gun Director and crew. It may be an aloft director tower or an armoured director tower.

*Director Control Tower* is similar to the above except that it contains the control personnel in addition to the crew for the director sight.

*Director Telescope* is the telescope mounted in the director which the Director Layer uses in director firing. It is not stabilised.

*Gyro Telescope* is the telescope mounted in the director in which the line of sight is stabilised in elevation by a gyro-controlled prism.

*Line of Sight* is the line through the director telescope to the target.

*Angle of Sight* is the angle measured in the vertical plane between the line of sight through the director telescope and the horizontal plane.

*Vertical Sight Plane* is the vertical plane containing the line of sight.

*Roll* is the movement of the ship about the longitudinal axis.

*Pitch* is the movement of the ship about the athwartships axis.

*Level Angle* is the angle between the deck plane and the horizontal measured in the vertical sight plane or in the vertical plane through the gun. The level angle is positive when the angle of sight is less than director elevation, i.e. when the ship rolls towards the target.

*Cross-level Angle* is the angle between the deck plane and the horizontal measured in a vertical plane at right angles to the vertical sight plane. The cross-level angle is right when it makes the telescopes and gun bores point to the right.

*Undisturbed Line of Sight* is one which is not thrown off the target by the setting of range or deflection. All modern directors have undisturbed line of sight for both Layer and Trainer.

*Stabilised Line of Sight* is one which is kept continuously on the target by some form of gyro stabilisation. Most L.A. directors have a telescope stabilised in level for the Layer and Trainer. The latest directors can also be stabilised in training for cross level and yaw.

*Director Elevation* (*D.E.*) is the angle in the vertical plane between the line of sight to the target and the deck plane of the ship.

Thus director elevation = angle of sight $\pm$ level angle.

*Director Setting* is the angle transmitted by the low-angle Director Layer to the guns. It is mechanically separated from the Director Elevation arrangements so that the Director Layer can stop his pointers before the telescopes roll onto the target to enable the guns to be layed with the maximum accuracy.

Gyro firing gear is arranged to operate when director setting equals director elevation, or when they are separated by the time interval compensation angle which cancels the errors that would otherwise arise from the movement of the guns and the slight delay which occurs before the shell leaves the muzzle.

In disturbed line of sight directors the director setting transmitted to the guns by the Director Layer will include tangent elevation and dip for the range set on the director sights.

*Director Training* (*D.T.*) used to be called Line of Sight Training. It is the angle between the fore and aft line of the ship and the line of sight of the datum director measured from 0°–180° to port and to starboard. In the case of non-datum directors a convergence correction has to be added.

> *NOTE :*
>
> The above definition applies equally to disturbed and undisturbed line of sight directors. In the case of the former, however, the angle of training showing on the dial in the director will not be the same as director training since it will include gun deflection.

*Tangent Elevation* is the elevation above the line of sight which must be applied to a gun to make the shell travel the distance desired.

*Gun Elevation* is the angle in the vertical plane between the axis of the gun and the deck plane of the ship.

It is thus director elevation + tangent elevation + dip (from the director to the standard level).

*Gun Training* is the relative bearing of the axis of the gun from the fore and aft line of the ship. It is made up of director training plus deflection plus cross-levelling training correction. Where centralised convergence gear is fitted in the T.S., the outgoing transmissions are known as " Forward " and " After Gun Training ".

*Standard Level* is the arbitrary level (usually the mean height of the gun bores) from which the dip height is measured when calculating the dip corrections to be applied.

*Datum Height* is the height of the director telescope above the standard level.

## ELEVATION CORRECTIONS

21. *Dip* is a correction to elevation to allow for the vertical distance between the guns and the director.

*Tilt* is a correction to elevation to allow for the different angles to the mean plane of the ship, which the roller paths of the mounting and the directors may make.

*Displacement* is a correction to elevation required by each mounting to allow for the distance that it is separated laterally from some datum point in the ship. In most ships this point is the datum director, but not necessarily so. For instance, in *Nelson* and *Rodney* the datum for the main armament is " B " turret.

## TRAINING CORRECTIONS

22. *Convergence* is a correction to training to allow for the lateral distance between the director and each individual mounting.

*Cross-level Training Effect* is the correction which must be applied to gun training to allow for the cross-level angle.

*Drift* is the lateral movement of the shell from the straight line along which it is fired due to the spinning motion imparted to it as it travels down the bore. In some disturbed-line-of-sight directors the necessary correction is made in the sight itself. In all modern systems it is made in the fire-control table.

*NOTE : The above corrections are fully explained in Chapter IV.*

## FIXED SIGHT

23. *Director Fixed Sight* is a certain range setting which will produce an elevation that will ensure getting hits on some part of a target at any range within a fairly wide zone, provided the correct point of aim is used.

*Fixed Sight Elevation* is the angle through which the range-setting mechanism of the R/E unit must be moved from its zero position to produce the elevation mentioned in the preceding definition.

*Fixed Sight Mark* is the mark to which the range mechanism must be set in order to produce the fixed sight elevation from the R/E cam.

*Fixed Sight Zone* is the range zone in which the fixed sight elevation is effective.

## DIRECTOR INSTRUMENTS

24. *Range/Elevation Deflection Unit* (*R/E and D unit*) is a self-contained mechanism mounted in the director tower of earlier ships with undisturbed-line-of-sight directors. By

setting range on the unit the tangent elevation required for that range, plus allowance for dip, and tilt of the director is added to the director elevation and transmitted to the elevation receivers at the guns. Deflection is likewise added to director training and transmitted to the training receivers.

*Range and Elevation Unit* (*R/E unit*) is similar to the R/E D. unit except that it deals only with range. In ships fitted with A.F.C.T. VI and later and in all ships fitted with the A.F.C.C. this unit is incorporated in the fire-control table.

*Elevation Receiver* is an instrument mounted near each gun and shews electrically the elevation transmitted from the controlling position, and mechanically, the movement of the gun. It may or may not incorporate corrector mechanism.

*Training Receiver* is similar to the above but shews training instead of elevation. Correctors may or may not be fitted.

*Time Interval Compensating Gear* (*T.I.C.*) is a unit mounted in the D.C.T. which automatically calculates the necessary forecast in gyro firing to allow for the movement of the guns and the slight time lag before the shell leaves the muzzle, and applies it to the gyro firing gear.

## FORMS OF FIRE

| | |
|---|---|
| 25. Low Angle (L.A.) fire | Fire at all targets on the sea or ashore. |
| High Angle (H.A.) fire | Fire at all targets in the air. |
| Visual Fire .. .. .. | Fire at all targets that can be seen. |
| Blind fire .. .. .. | Fire at all targets that cannot be seen. |

## METHODS OF LAYING

| | |
|---|---|
| 26. Visual laying .. | Guns are laid by direct observation from a director. |
| Gyro laying.. .. | Guns are laid with reference to a datum provided by a gyro. The target may or may not be in visual sight. |
| Radar laying .. | Guns are laid with reference to a datum provided by a radar set. |
| Datum laying .. | Guns are laid with reference to a datum provided by an instrument other than a gyro or radar set (e.g. bombardment level). |
| Local laying .. | Guns are laid by direct observation from their own sights. |

## METHODS OF TRAINING

| | |
|---|---|
| 27. Visual training .. | Guns are trained through the F.C. table or clock by direct observations supplied by the director telescope. |
| T.S. training .. | Guns are trained through the F.C. table or clock from the bearing clock, based on the enemy settings in use. |
| Radar training .. | Guns are trained through the F.C. table or clock from information supplied by a radar training tube. |
| Datum training .. | Guns are trained through the F.C. table from observations supplied by an instrument other than the director telescope or radar set (e.g. a dial sight). |
| Local training .. | Guns are trained by direct observations from their own sights. |

## METHODS OF FIRING

| | |
|---|---|
| 28. Director firing .. | All guns are fired by a single Layer at the director sight. |
| Gyro firing .. .. | The firing circuits are closed by the gyro firing gear. |
| Radar firing .. | The guns are fired against aircraft or other targets by an automatic radar-controlled firing switch such as the auto-barrage unit. |
| Firing by directing turret or gun .. | All guns are fired by the Layer of the directing turret or gun. |
| Local firing .. .. | The gun is laid and trained by following the director or table and fired by the local arrangements at the gun. |
| Gunlayer's firing | The gun is laid and fired by the Gunlayer or local sight Layer, but the training is by director. |
| Quarter's firing .. | The gun is laid, trained, and fired by means of its own local sighting and firing arrangements. |

*The terms defined under the above three headings are more fully explained in Chapter III.*

29–34.

## CHAPTER III

# METHODS OF AIMING AND FIRING THE GUNS

### SECTION 1. METHODS OF AIMING WITH A DIRECTOR

35. Although in the following paragraphs the methods of pointing the director are referred to as *Visual Fire, Blind Fire,* etc., it must be clearly understood that these terms do not in fact refer to the method of firing the guns but only to the method of pointing the director at the target.

Methods of laying and training the director can be divided broadly into *Visual* when the target can be seen by the Layer and Trainer, and *Blind* when it cannot. The Layer and Trainer can, however, use the methods of laying and training described below independently of each other, e.g. the Layer can use gyro laying while the Trainer is using " table " or " radar " training. The methods of laying are therefore described separately under the headings of " visual " and " blind " fire.

## VISUAL FIRE

### METHODS OF LAYING

#### Visual Laying

36. The guns are laid by direct observation from the director, the Director Layer adjusting his point of aim by movement of the director elevation handwheel.

#### Gyro Laying

37. The guns are laid with reference to a datum provided by a gyro. When the target is visible, this datum is corrected for gyro wander in the vertical plane of sight by a manually operated adjustment by which the stabilised line of sight is kept on the point of aim.

#### Local Laying

38. The guns are laid by direct observation from their own sights.

### METHODS OF TRAINING

#### Visual Training

39. The guns are trained direct from observations supplied by the director. The gun training based upon this information may or may not be transmitted through the F.C. table to the guns. The Director Trainer can use his unstabilised or stabilised telescopes or binoculars for this type of fire.

#### Datum Training

40. The guns are trained through the F.C. table from observations supplied by an instrument other than a radar set or director, e.g. a dial sight. This is usually mounted on the director tower and the reception of training in the T.S. is exactly the same as for visual training. The Trainer, however, instead of looking directly at the target which is being engaged, looks at some datum point, the angle from which to the target is known. With this angle set on the dial sight, the line of sight of the director is kept trained in the line of sight to the target even though the latter is not in fact visible. This method of training is included in the visual category since the Trainer is using an external datum in the form of an aiming point rather than an artificial datum provided by a fire-control table or radar set.

## BLIND FIRE

### METHODS OF LAYING

#### Gyro Laying

41. The guns are laid with reference to a datum provided by a gyro. The gyro, if controlled for wander by some form of electro-magnetic mercury control, will give a sufficient degree of accuracy for continuous blind fire. Where such a control is not fitted the accuracy of stabilisation of the gyro is not sufficient, except in the case of the " P " sight, for blind fire to be carried out for more than a short time after some visual datum for the correction of the gyro has disappeared.

#### Datum Laying

42. The guns are laid with reference to a datum provided by some means other than a gyro or radar set. This in most cases will be a bombardment level, which, if there is little or no motion on the ship, will provide a reasonably accurate horizontal. Since, however, it works on the principle of a spirit level, the bubble will surge to and fro if there is any motion on the ship, and it is then necessary for the Layer to " mean " the oscillations. Under such circumstances the datum provided is far from accurate, though it is sufficiently good for bombardment shoots of the " Area " type if no other method of laying is possible.

The bombardment level used in conjunction with the " P " sight as a method of correcting the wander of the gyro with no visible horizon, provides a more accurate datum than the level used on the unstabilised part of the standard type sight, and may be considered to come under the heading of datum laying.

With the fitting of electro-magnetic mercury control to all types of sights, datum laying should seldom be necessary unless the gyro has broken down.

**Radar Laying**

43. The use of the radar set as a datum for laying is not yet possible. When future developments make it so, the elevation of the sight will be controlled from the radar set just as the training can be at present.

## METHODS OF TRAINING

**Table Training**

44. The guns are trained through the fire-control table and the Director follows the table-training pointer in the director-training dial. The initial bearing of the target is tuned in to the F.C. table, and the rate of change of bearing is calculated in the bearing or speed-across clock, on the basis of own and enemy settings and the range in use, and added to the initial bearing to make director training. The bearing produced is transmitted to the D.C.T. which is trained by a member of the director crew (preferably not the Trainer who should be free to search for the target visually), who keeps the mechanical pointer in the director-training dial in line with the table-training pointer.

**Radar Training**

45. The guns are trained through the fire-control table or clock from information supplied from a radar training tube. This tube may be located in the T.S. or in the director or in both. If it is in the T.S. the procedure is exactly the same as in table training so far as the director crew are concerned, i.e. the tower is trained by keeping the mechanical pointer in the director-training dial in line with the table-training pointer. In the T.S., however, the table is kept tuned by the bearing-plot operator to the bearing indicated by the training tube mounted over the plot. The bearing of the target is thus continuously observed by the radar set instead of being calculated by the table as in table training.

If the training tube is mounted in the director tower, the procedure in the *T.S.* is exactly the same as for visual fire. The tower is trained direct from the training tube in the director. This should be done by some member of the crew other than the Trainer in order that the latter may be free to search visually for the target if there is any possibility of a visual sighting.

46. Where tubes fitted in D.C.T. and T.S. the Control Officer must indicate which one is to be used. To do this he will give one of two orders :—

"**Switch to director**", which will always be used for visual fire and also for blind fire when the *tube in the D.C.T. is being used* for radar training.

or "**Switch to T.S.**", which will be used whenever the target bearing is transmitted from the bearing clock. This will include occasions when "table training" or "radar training" using *the tube in the T.S.* is providing the bearing.

## SUMMARY OF METHODS OF LAYING AND TRAINING

| | LAYING | TRAINING |
|---|---|---|
| *VISUAL* | Visual<br>Gyro<br>Local | Visual<br>Datum<br>Local |
| *BLIND* | Gyro<br>Radar (not yet)<br>Datum | Table<br>Radar |

## CH. III. SECTION 2. METHODS OF FIRING THE GUNS

47. The following methods of firing are given in the order in which they would normally be used in the event of breakdowns or action damage. An exception is radar firing which at present is only used against aircraft, or fast targets such as "E" boats; the use of which is therefore governed by the probability or otherwise of engaging targets of these types.

(*i*) **Gyro Firing.** This is the primary method of firing low-angle guns. The firing circuits are closed by a gyro-controlled contact arm at the director, or, in the case of the "P" sight, by a gyro firing switch, provided the firing pistol is also pressed. Gunlayers and Trainers follow their director pointers or the mounting is controlled by an R.P.C. system.

(*ii*) **Director Firing.** All guns are fired by a single Layer at the director sight. The firing circuits are energised at the moment at which the Director Layer presses his trigger. The guns are laid and trained as in (*i*).

(*iii*) **Local Firing.** The guns are laid and trained as in (*i*) but are fired by means of the local firing arrangements at the mounting.

This method of firing is used at guns 5·25 in. and below, when the firing circuits from

the director break down but the elevating and training circuits are intact. It should give smaller range spreads than Gunlayer's firing in spite of pointer-following errors arising from the fact that the Director Layer is laying continuously.

(*iv*) **Firing by Directing Turret or Gun.** All guns are fired by the Layer at the directing turret or gun. Very few ships are fitted for this type of fire.

(*v*) **Gunlayer's Firing.** The gun is laid and fired by the Gunlayer or local sight layer, but the Trainer continues to follow the director pointers. This method of firing is used in ships with guns larger than 5·25 in. under similar circumstances to (*iii*) in other ships, and in the latter if the director elevation circuits alone break down.

(*vi*) **Quarters Firing.** The gun is laid, trained, and fired by means of its local firing and sighting arrangements. This system is used when the director training circuits have broken down.

48–54.

## CHAPTER IV

## ALLOWANCES REQUIRED IN A DIRECTOR SYSTEM

### GENERAL

55. Since the director is situated at some distance from the guns, which are themselves separated from each other, certain allowances have to be made in the director system in order that the fall of shot from all guns may, theoretically, be at one point.

Owing to variations in magazine temperatures and in the wear of individual guns, allowances must also be made for the consequent differences of muzzle velocities from normal.

### CORRECTIONS TO ELEVATION

#### Muzzle Velocity

56. The muzzle velocity of each gun varies with the temperature of the charge and with the wear of its bore, the latter depending upon how many rounds have been fired from it. The effect that such variation will have upon the fall of shot depends upon the range at which the gun is being fired.

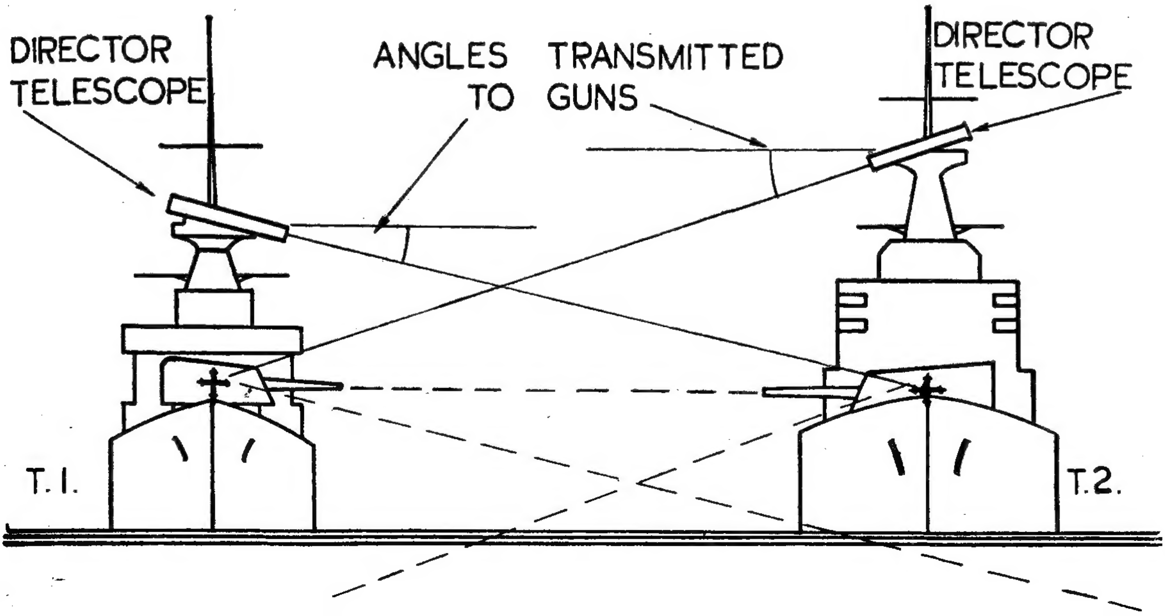
The range-to-elevation conversion cams, whether situated in the director or in the fire-control table, are cut so that they provide the necessary elevation for a given range at some particular M.V. In new construction ships the M.V. selected is always that given in the range table for the particular gun which the director controls, and is based upon a standard charge temperature of 70 degrees.

The elevation receivers at each gun have incorporated in them a corrector mechanism which is set to the M.V. of the gun and the mean temperature of the magazine, from which the charge has been taken. The mean over the previous 24 hours is used when calculating the effect that temperature will have on muzzle velocity, since cordite reacts very slowly to changes in temperature. A drive of range, which may be set electrically from the T.S. or by hand at the gun, is fed into the corrector, the output from which offsets the mechanical pointer in the elevation receiver dial. Re-alignment of this pointer with the electrical pointers applies the required correction.

#### Dip

57. Dip is the correction to elevation to allow for the fact that the guns and the director are at different heights above or below the standard level.

*Diagram 1.* **The Correction for Dip.**



In the *Diagram 1* tangent elevation is disregarded and the pecked lines show the elevation which the director transmits to the gun when laid on the targets T1 and T2. The points of aim (+) are assumed to be at the same heights as the guns, and, disregarding all other factors, the guns should in each case be laid horizontally in order to hit the targets. The directors are, however, transmitting angles of depression whose size depends upon the range of the target and the height of the director above the gun. A correction must therefore be made to the elevation transmitted to the guns to compensate for this.

58. In a ship the guns will be at several different levels. A mean is therefore selected, which is known as the standard level, and the dip correctors at each gun allow for the difference in height of each gun from that level. The allowance for the height of the director above this standard level is made in the range-to-elevation conversion cams in the director or in the fire-control table (A.F.C.T. VI and later tables have separate dip mechanisms). Instead of cutting them to give the straightforward conversion from range into tangent elevation they are shaped to convert any range setting into tangent elevation + dip to the standard level at that range.

**Tilt**

59. When a ship is built every effort is made to machine the roller paths of all mountings and the directors which control them, so that they are parallel to the waterplane of the ship when the ship is upright.

It is found in practice that this is only possible within certain limits, and the mountings and directors have usually slight tilts relative to each other. This does not matter when the Gunlayer of each mounting is applying the elevation relative to his own roller path, by laying his telescope on the target. When, however, he is following director pointers which tell him the elevation of the Director Layer's telescope relative to the roller path of the director it matters very much whether or not the two paths are exactly parallel. If they are not, the gun will be elevated wrongly by the difference between them, and the fall of shots in a broadside may be very widely separated.

This error in elevation will vary according to the amount of maximum tilt between any mounting and the director and the bearing on which it occurs.

60. Tilt-correcting mechanisms are fitted at most mountings and directors and make the necessary elevation corrections to allow for these divergences from the datum plane of the mountings. These correctors are described in *Instructions for the Conduct of Tilt Tests*, as is the method of determining the tilt of any roller path by means of a tilt test.

61. When considering the measuring and the correction of tilt, the following terms are used :—

(*i*) *Measured Tilt* is the angle between the plane of any mounting and the earth's horizontal plane at the time of taking the readings.

(*ii*) *Testing Tilt* is the difference of the measured tilt of a mounting or director from the datum plane of that armament. The methods of calculating the datum planes of different armaments are described in *Instructions for the Conduct of Tilt Tests*. This tilt is set at all mountings when doing a director test and at the directors at all times.

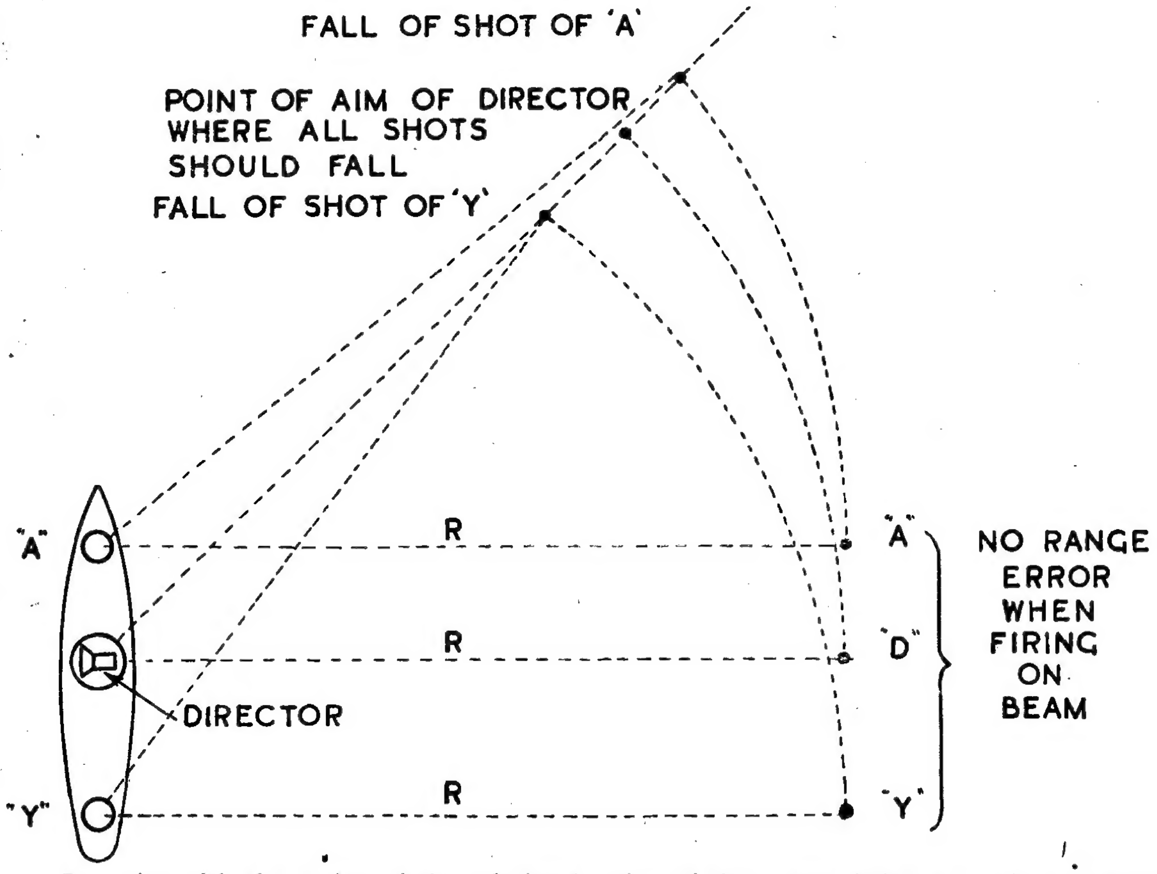
(*iii*) *Firing Tilt* is the testing tilt plus or minus the displacement correction. This tilt is set at all gun mountings at all times other than when doing director tests.

The use of testing tilt is a convenient way of reducing the size of the tilt corrections that have to be applied, since obviously the maximum amount that has to be applied to bring the most divergent mounting to the mean of all mountings will usually be less than that required to bring it into line with the true horizontal.

**Displacement**

62. Displacement is a correction to elevation to allow for the effect on range of the lateral separation of the mountings from some datum point which usually is, but need not always be, the director.

*Diagram 2.* **The Correction for Displacement.**




It varies with the cosine of the relative bearing of the target, being a maximum when firing right ahead or right astern and nothing on the beam, and is due to the fact that, although the same range (R) is set at all guns, they are, in fact, at different ranges from the target.

Although for any given bearing the correction measured in yards is the same at any range, the elevation necessary to produce that distance varies at each different range. To make this correction fully accurate would require complicated gear which the errors involved in an approximation do not warrant. A suitable fighting range is therefore selected for each class of ship and the correction is calculated for that range. In the case of capital ships this is 15,000 yards, for cruisers 10,000 and for destroyers and sloops 6,000 yards.

63. The correction thus becomes dependent upon only one variable, namely the cosine of the relative bearing. Tilt similarly varies with the cosine of relative bearing, although the basic starting point is not the fore-and-aft line but the bearing on which tilt is highest. It is thus convenient to correct for both tilt and displacement in the same mechanism. This is done by setting what is in effect a " fudged " tilt correction, which includes the displacement correction and is called firing tilt.

## CORRECTIONS TO TRAINING

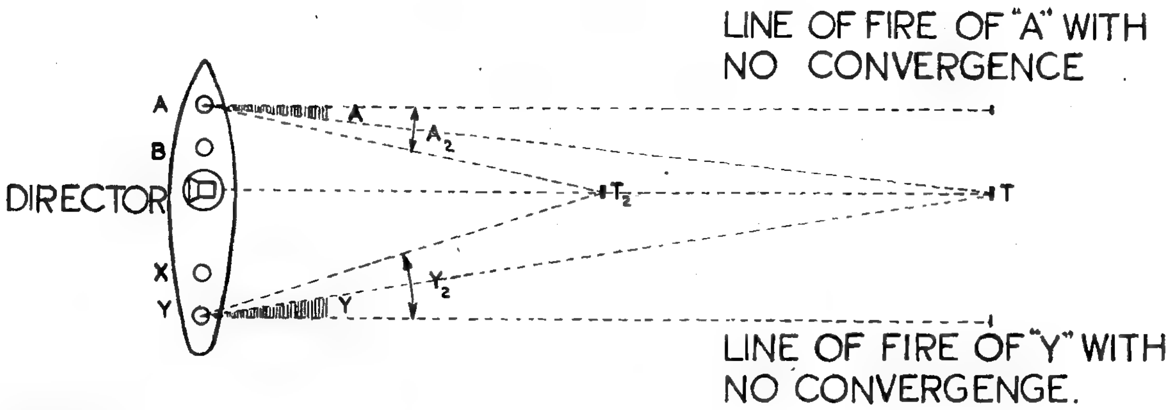
**Convergence**

64. Convergence is a correction to training by which the line of sight of all guns is converged on to the line of sight of the Director at the target. Where more than one Director can control the same armament the non-datum director should be corrected on to the line of sight of the datum director. In ships fitted with R/E and D units this convergence between the directors is allowed for, but where the deflection is added in the fire-control table the resultant error is accepted when the non-datum director is controlling, except in certain modern systems where it is allowed for in the director training unit in the D.C.T.

At any given mounting the correction varies with the range and with the sine of the relative bearing on which the gun is trained, being a maximum on the beam and zero when firing fore and aft. The effect of range can be seen in *Diagram 3,* the angles $A_2$ and $Y_2$ being quite clearly bigger than the corresponding angles A and Y at the longer range.

65. The correction is made at certain mountings in the training receivers by a corrector mechanism which can be set for the lateral distance between the mounting and the director and which is fed with the range and bearing of the target. This correction is only accurate between certain limits of range. These limits vary with different equipments but are normally from 1,000 yards up to within 2,000 or 3,000 yards of the extreme range of the gun. In some modern ships convergence correction is applied in the T.S.

*Diagram 3.* **The Correction for Convergence.**




**Cross Level**

66. This training correction is not due to any complication introduced by the director system, and applies equally to all guns. Reference is, however, made to it here since it is only in a director system that an attempt is made to deal with it.

The error is known as canted-trunnion error and is caused by the canting of the trunnions of the sight or of the gun. Its value depends upon the elevation of the gun (and hence the range) and the angle of inclination of the trunnions in a plane at right angles to the vertical plane of sight.

The gear with which it is corrected is known as cross-levelling gear and is mounted in the director control tower. The operation of the gear is fully described in Part 16 of this series, and further reference is made to it in Chapter VI, Section 2 of this handbook.

**Drift**

67. Although in modern ships this is not corrected by any mechanism in the director system it is mentioned here as it has to be taken into consideration when deciding on the settings to be put on the fire-control table when doing a director test.

The correction is necessary because the projectile does not travel straight after leaving the gun but drifts away to the right during its flight. This is because the pressure of the wind caused by its flight through the air acts below the centre of rotation of the projectile. The projectile has gyroscopic properties owing to the rotation given to it by the rifling, and this pressure applied eccentrically below the nose of the shell causes a precession to the right of the line of flight. This correction is calculated in the A.F.C.C. or A.F.C.T. and applied direct to gun training or included in gun deflection.

When doing a director test it is therefore necessary to set range on the table to zero when testing for line, or the unwanted drift correction is added in (*see Chapter XIV*).

## SUMMARY OF CORRECTIONS AND METHODS OF MAKING THEM IN MODERN INSTALLATIONS

68. Those that are taken into account in most modern fire-control systems are :—

| CORRECTIONS | WHERE MADE |
|---|---|
| *FOR ELEVATION* | |
| Dip .. .. .. .. .. | 1. Director to the standard level. By the shape of the range cam in the R/E conversion unit.<br>2. Guns to the standard level. By corrector mechanisms at the elevation receivers of all guns. |
| M.V. and Temperature .. .. | The R/E cam is shaped to give the correct elevation for range-table M.V. at normal temperature. Variations from this standard are made in the corrector mechanism in the elevation receiver at each gun. |
| Tilt .. .. .. .. .. | In tilt correctors at all guns and directors. |
| Displacement .. .. .. | Incorporated in the tilt correction. |
| *FOR TRAINING* | |
| Convergence .. .. .. .. | Corrector mechanisms in the training receivers at all guns or in the gun training transmission in the T.S. |
| Drift .. .. .. .. .. | In the fire-control table or clock in which it is added to deflection. |
| Cross Levelling .. .. .. | A special instrument is fitted in the director which measures the cross-level angle, calculates the necessary correction and adds it differentially to gun training. |

# CHAPTER V

# NOTES ON DIRECTOR LAYING AND TRAINING

## SECTION 1. LAYING

### RESPONSIBILITIES OF THE DIRECTOR LAYER

75. The responsibilities of the Director Layer are very great; on his skill and co-operation with the Control Officer and the remainder of the Director crew depends the success of the firing. It is almost impossible for anybody to keep a check on what he is doing and it is therefore essential that he should have a very high sense of responsibility. He should also cultivate a calm and steady manner, as any sign of nervousness on his part will disturb the rest of the crew and the Gunlayers.

There should be a complete understanding at all times between the Control Officer and his Director Layer. The latter should never hesitate to admit and report a mistake at once, and the former by making himself thoroughly conversant with the Layer's job, should acquire an understanding of its many difficulties which will lead to successful co-operation and mutual confidence.

76. On the laying skill of the Director Layer depend the following important points :—

(*i*) The **accuracy** with which each salvo is fired, i.e. it must fall at the range intended by the control. Since it is a pre-requisite for a successful shoot that shots fall in line with the target, the Director Layer must also be responsible that no shot is fired unless the director is on for training.

(*ii*) The **spread** of the salvos. The importance of keeping the spread small is obvious, and the greatest cause of large spreads is " Follow-the-pointer errors " at the guns. The Director Layer can make the task of the Gunlayers very much simpler by considerate working of his director-setting handwheel. The fitting of remote power control to the guns affects the degree of consideration required under various conditions. This is discussed in the section on R.P.C. in *Chapter VII*.

(*iii*) That part of the **rate of fire** which depends on the Director Layer's time on aim after the fire gong has rung. This is particularly important in cruisers and destroyers whose guns have a high rate of fire and which depend to a certain extent on smothering the enemy with their high salvo output. Accuracy must never be sacrificed for speed, but the time between the ringing of the fire gong and the firing of the guns can be greatly reduced if the Director Layer trains himself to judge the firing interval, and hence the moment at which the fire gong will ring, and works his director elevation handwheel in such a way that he is very nearly on the point of aim when the gong rings.

77. It is emphasised that " Time on Aim " quite correctly comes last, for although it is important to maintain a good rate of fire, accuracy must not be sacrificed for speed.

Notwithstanding the efficiency of any individual, accuracy and speed in firing is not attainable, unless both Layer and Trainer have been trained to work in close co-operation with one another; the necessity for such co-operation is most apparent, and is most easily tested, during alterations of course. If, during practices, arrangements are occasionally made for Director Layers and Trainers to exchange their duties with Gunlayers and Trainers a mutual respect for each other's difficulties can be secured.

### REPORTS TO BE MADE

78. The Director Layer has to make certain reports to the Control Officer to keep him informed of the situation as far as the Layer and Trainer are concerned.

These should be as brief as possible and the Director Layer should be particularly careful not to make his report while the Control Officer is passing orders to the T.S. The Director Layer must also realise that the Control Officer is wearing headphones and that it is no good whispering his reports either in the heat of action or the turmoil of a practice shoot.

79. The Director Layer should always make the following reports :—

(*i*) When put on a lookout bearing or whenever a target is pointed out by Evershed, he should report **" Director On "** when on the bearing ordered or when the Evershed needle is central. This report is of particular importance at night when it tells the C.O. that the Layer and Trainer ***cannot see the target***.

(*ii*) Whenever the Director Layer can actually ***see*** the target he should report **" Director Target "**. This again is particularly important at night when it tells the C.O. that he can open fire as soon as the guns are ready.

(*iii*) In directors in which a radar training tube is fitted, the Operator, when he has trained the director on to the bearing indicated by the echoes in the tube, is to report **" Radar Target "**.

(*iv*) Whenever the Director Layer fires a badly laid shot he must report the fact to the C.O. in order to prevent the latter being misled into making a spotting correction based upon an entirely false fall of shot. The Control Officer does

not, however, normally give a correction of less than 100 yards, and it is therefore undesirable for the Director Layer to report **" Bad shot ; High, (or Low) "** if the laying error is less than the equivalent of 100 yards at the range in use.

80. The following table gives a guide as to when " bad shots " should be reported :—

| RANGE IN YARDS | ERROR IN AIMING MEASURED IN TARGET HEIGHTS (30 FT. B.P.T.) WHICH WILL CAUSE AN ERROR OF 100 YARDS IN FALL OF SHOT USING FULL CHARGES | | | |
|---|---|---|---|---|
| | *16-in.* | *8-in.* | *6-in. Mk. XXIII* | *4·7-in.* |
| 20,000 | $3\frac{1}{4}$ | 6 | 10 | — |
| 15,000 | 2 | 3 | $4\frac{1}{2}$ | $\frac{14{,}700 \text{ yds.}}{11}$ |
| 10,000 | 1 | $1\frac{1}{4}$ | 2 | 4 |
| 5,000 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 1 |
| 2,000 | $\frac{1}{6}$ | $\frac{1}{7}$ | $\frac{1}{6}$ | $\frac{1}{5}$ |

When using reduced charges the number of target heights will be larger.

When making his report the Layer should remember that it is the " *High* " or the " *Low* " that the C.O. wants to hear rather than " *Bad shot* " and should therefore raise his voice for this latter part of the report.

## THE ORDER " WAIT "

81. This order may be given by the Control Officer at any time to stop a salvo being fired after ordering **" Shoot "** or the fire gong being rung. The Director Layer should repeat it, and should not fire until **" Shoot "** is again ordered and the fire gong rung.

## STANDARD POINT OF AIM

82. (*i*) **Ship Target.** Point where the vertical through the foremast cuts the horizontal through the forecastle deck. At very short ranges, *i.e.* 1,000 yards or less, the point of aim should be the intersection of the foremast, or leading edge of the target, with the ***waterline.***

(*ii*) **Practice Target.** Leading edge for line. Top of the canvas for elevation.

## HUNTING THE ROLL

83. This means moving the director setting handwheel so that the director telescope crosswires in director firing and the collimator in gyro firing are in such a position relative to the target, that, when the fire gong rings there is a minimum of movement required to get " on " and therefore a minimum time on aim. The final movement may be made by ship's motion or by a final turn of the D.S. handwheel. In order to avoid pointer-following errors the crosswires should always be brought on to the point of aim by the roll of the ship rather than by a movement of the D.S. handwheel. When R.P.C. of the mountings is fitted, especially in conjunction with the Mark VI Director, the problem is not quite so straightforward. This is discussed in the section on R.P.C. in *Chapter VII.*

To be successful in hunting the roll requires constant practice and a knowledge of the ship's behaviour under varying conditions of weather and rudder. The Director Layer must get to know the peculiarities of his own ship as soon as possible after joining.

## CONSIDERATION FOR GUNLAYERS

84. When the guns are not fitted with a system of R.P.C. it is essential for the Director Layer to make a slight pause in the movement of the electrical pointers so that the Gunlayers can get their mechanical pointers in line before the gun fires.

The length of pause required depends on the type of gun-elevating gear and its condition and also on the ability of the Gunlayer. It is to improve the latter that daily pointer-following drill is essential.

A reversal of the pointers just before firing will cause large pointer-following errors at all types of mountings, and should be avoided at all costs. In handworked guns no pause is necessary as the Gunlayers should be on continuously, provided the movement of the electrical pointers is reasonably smooth in one direction.

85. When R.P.C. is in use, the Director Layer, theoretically, need have no consideration

for pointer-following at the guns. But to allow for sluggishness in power follow-up and for the case where R.P.C. has failed at one or more mountings, the elevating handwheel will frequently have to be stationary for a brief period before firing. This aspect of R.P.C. is discussed in *paras. 145 and 146*, although insufficient experience of its operation has so far been obtained to admit of an authoritative ruling.

86. The R/E and D. operator or the range and deflection operators at the fire-control table or clock also control the movement of the pointers at the guns. When a large alteration of range is made it is important that the Director Layer does not fire until the elevation hunter has settled down and the electrical and mechanical pointers of the elevation repeat are once more in line.

Where the R/E D. Operator is in the director, he can easily indicate this to the Director Layer by reporting "**Sights moving**" and "**Sights set**" as is done at a gunsight or disturbed line of sight director. Where the addition of range and deflection is made in the table, the Range Operator must not ring the fire gong until he sees that the repeat dials or counters of range and deflection are showing the same as the mechanical ones on which the corrections have been set.

### FIRING UNDER RUDDER

87. In ships fitted with magslip transmission, no difficulty will be experienced, but where other systems of transmission are used the Director Layer must realise that the director can train much faster than the electrical transmission to the turrets can follow. He should therefore be careful not to fire until the gun-training repeats are once more in line. Neither he nor the trainer can see these when they are using their telescopes, and he will therefore have to learn from experience the time interval that he must allow for various rates of training.

### CHANGING THE METHOD OF FIRING

88. The Layer must always be ready to change over instantly from gyro to director firing and vice versa should conditions warrant it, or should a breakdown in the firing circuits necessitate it.

When T.I.C. gear is fitted, gyro firing is the most accurate method of firing under all conditions except the very rare one of a flat calm with no motion on the ship. The normal method of fire in ships so fitted will therefore be by gyro using T.I.C. gear.

### RELEASE OF FIRING PISTOL OR PEDAL

89. The firing pistol or pedal must be released as soon as the guns fire in both gyro and director firing or there is a risk that guns will fire as soon as brought to the ready. This is particularly important in salvo firing when the interval before guns are brought to the ready is very short.

### GYRO AND DIRECTOR MISSFIRE PROCEDURE

90. A missfire in gyro firing is caused by the roller contacts failing to complete the circuit to the gyro relay. This means that neither the main nor auxiliary (port or starboard in later ships, *see Chapter XII*) director circuits will be energised and none of the guns will fire. The Director Layer will thus be the only man to know that it has occurred.

#### 1st Missfire in Gyro Firing

91. Director Layer reports "**Gyro Missfire**" for the information of the Control Officer, and moves the Director Change-over pistol to Gyro Auxiliary.

#### 2nd Missfire in Gyro Firing

92. The Layer reports as before and moves the D.C.O. pistol to "*DIRECTOR*", at the same time shifting his eye to the director binocular. The trainer should continue to use his stabilised telescope to retain the advantage of a stabilised line of sight.

With the D.C.O. pistol at "Director", both main and auxiliary firing circuits will be energised. Half the guns are connected to the one and half to the other when all their change-over switches are showing the same. This also applies to the new system of port and starboard circuits.

The Director Layer will therefore probably not be able to detect the first missfire in director firing, since half the guns will fire and the remainder will change over their circuits in accordance with the gun drill.

93. Thus if he presses his trigger and no guns go off, it is at once assumed that both director-firing circuits are out of action and the drill for the **3rd Missfire** is therefore as follows :—

Director Layer reports "**Director Missfire**". He then continues to lay on the target *continuously*.

The Control Officer passes to the T.S. for transmission to the guns the order: "**Director Missfire, Gunlayer's Firing**", in the case of 6-in. guns and above; or "**Director Missfire, Local Firing**" in the case of 5·25-in. guns and below. The difference between these two is described in *Section 2 of Chapter III*.

94. In the case of the "P" sight there are only two positions of the D.C.O. pistol, both main and auxiliary (or port and starboard) circuits being energised with the switch at "*GYRO*"

or " *DIRECTOR* ". The drill for the second missfire in the case of the ' P ' sight is therefore as for the third missfire at sights fitted with the three-position change-over pistol.

**SHADES AND FILTERS**

95. Shades and filters are supplied for use at directors, and also at gun sights. The shades are for eye protection when a searchlight is being used as a point of aim, and the filters cut out unwanted light, thus making the object more distinct. Shades are of neutral tint, and filters red and yellow.

In binocular and monocular telescopes of new construction the shades and filters are incorporated in the design of the instrument to facilitate adjustment under changing conditions.

## CH. V. SECTION 2. TRAINING

**GENERAL**

96. In order to obtain continuity of the bearing plot and to assist the Director Layer, the director should be trained continuously on the target. The Trainer does not, therefore, hunt the roll like the Layer, but trains so that his vertical crosswire is continuously on the point of aim. If the movement which he thereby transmits to the gun or turret training receivers is reasonably smooth the Gun Trainers should have no difficulty in following it accurately. It is most important, however, that the Director Trainer does not reverse the direction of his training handwheel just before the moment of firing, as this will inevitably cause large pointer-following errors at the training receivers with a consequently large line spread.

The Trainer should not attempt to forecast the movement of the ship, by training ahead of the point of aim and letting the yaw or alteration of course bring him on to the point of aim, as that would produce an irregular and inaccurate bearing plot. His object, from this point of view and from the pointer-following aspect, must therefore be to train as smoothly and as steadily as possible all the time.

97. The characteristics of good training are :—

(*i*) The consistency of the line spread. This is a measure of the consideration shown to turret or gun Trainers.

(*ii*) Accuracy of aim.

(*iii*) Smooth and regular bearing plots. This, however, is not always a clear indication, since the regularity is affected by other factors.

**CHANGING FROM VISUAL TO BLIND FIRE**

98. It is essential that at the moment of switching off the target visible lamp, the director should be exactly on the target for training. In order to ensure this blind fire should be started just before the target does in fact become invisible. It is recommended that when the trainer sees the target is about to become obscured, he should flash the target visible lamp on and off quickly to warn the bearing-plot operator that he is about to switch it off.

**SHADES AND FILTERS**

99. Exactly the same considerations apply to the use of these by the Trainer as by the Layer. (*See para. 95.*)

## CH. V. SECTION 3. LAYING AND TRAINING AT NIGHT

**GENERAL**

100. The principles of laying and training differ very little by night and day, though the application of those principles by night is liable to be more difficult. One of the factors which affect night fighting is that the first warning of the presence of the enemy will probably be a radar contact rather than a visual sighting. With existing equipment it is perfectly possible to engage invisible targets in blind fire, using a mercury-controlled gyro sight to provide the laying datum and radar training. To achieve satisfactory results using this method of fire demands a very high degree of co-operation between the Director Crew, Radar Operators and Control Officer, and constant practice is necessary to attain this.

**CAUSES OF DELAY BETWEEN A VISUAL SIGHTING AND THE DIRECTOR REPORTING "TARGET"**

101. At night, when targets are detected visually, there is frequently a long delay between the moment at which the target is sighted from the bridge and the time when the director is ready to open fire. There are several reasons for this, some of them due to the location and design of the Director Control Tower and some to the training and ability of the director crew.

102. Although it is not possible to make a complete separation between the causes attributable to the design of the instruments and their operation, the following classification is generally useful :—

(*i*) Causes inherent in the D.C.T. system.

(*ii*) Causes dependent on the design of existing D.C.T.s.

(*iii*) Causes involving personnel, routine, training, etc.

**(i) Causes inherent in the D.C.T. System**

Causes inherent in the director principle are, that the director has to start searching after the bridge has sighted the target, the director is higher than the bridge and is therefore adversely affected by waterline depression, and the instruments on the bridge are hand-held and hence more easily moved on to, and kept on, the target.

**(ii) Causes dependent on the design of existing D.C.T.s**

Causes inherent in the design of existing D.C.T.s are more numerous. The principal ones are outlined below.

(A) *Excessive lighting of instrument dials*

This is the largest single cause of the trouble and is in most cases due to failure to have dimmer switches fitted, their inefficiency in operation if fitted, the substitution of red lighting for white illumination, and above all, a lack of appreciation of the loss of night vision which occurs when reading a brightly illuminated dial. The radar training tube is a possible cause of similar interference, and both these sources of trouble must be eliminated by fitting effective dimming or shielding arrangements.

(B) *Lower power of Layer and Trainer's binoculars*

These are usually 7 power, whereas the T.B.I. binoculars are usually 10 power. The difference between these two on a clear night is 25% on the range.

(C) *Maintenance of D.C.T. Instruments*

These frequently become misted over by spray or condensation and on a dark night the user will not realise this. An anti-mistant such as Tedol should be used to prevent this, and binocular object glasses and Kent Clear View screens must be wiped periodically whether they appear to have misted over or not.

(D) *Restriction of View*

This is a controversial point, for there is in fact no physical obstruction when using binoculars, and the restriction of naked eye scanning should have no effect at night since the target should in any case be picked up in binoculars far outside the range of unaided optical vision. Since it is so frequently mentioned in sea reports, however, some effect must be presumed to exist, and is probably largely psychological. But a clearly defined allied effect, due to the control personnel being inside a closed structure, is that their eyes become accustomed to the level of brightness inside the D.C.T. instead of to that prevailing outside. Although the former will always be darker than the latter, this has a deleterious effect on the standard of night vision. It is therefore recommended that the inside of the D.C.T. be painted a matt white and that diffused lighting be provided to bring the illumination of the interior to the same brilliancy as that of the outside sky. This can be done satisfactorily by two very small lights covered by an orange filter (Chance's light orange or Chromex 2040) and controlled by a dimmer switch. Orange light has been found to be superior to red, blue, or white light for this purpose.

The best effect is produced when the interior lighting is adjusted to match the sky illumination outside the tower, though exact equality is not important. Even if by accident the interior lighting is made ten times as bright as the sky outside, it will not make the ship more visible but will function as a small amount of diffused lighting camouflage. The D.C.T. ports will sometimes appear to glow when viewed from the bridge, because when they match the sky they will be brighter than the surrounding parts of the ship which are usually considerably darker than the sky. This apparent glow is no real disadvantage but, if it is desired to eliminate it, a small patch of the interior of the D.C.T. immediately behind the ports may be painted a dull grey.

**(iii) Causes involving personnel, routine, training, etc.**

Misuse of existing gear by the D.C.T. crew, unsatisfactory routines, etc., are a prolific source of delay but are the most easily remedied.

Among these causes are :—

(*a*) *Loss of night vision due to premature or excessive illumination of the Layer and Trainer's graticules.*

It is most important that the intensity of illumination of the graticule be adjusted to the absolute minimum required for the existing conditions of light, and also that they are not switched on until the target is actually sighted. The Director Crew frequently do not appreciate this important point, or else the dimmer switch for the graticule illumination is so badly placed as to make any last-minute operation of the switch quite impracticable.

(*b*) *Loss of night vision due to discomfort and cold*

Director Crews closed up for long periods will inevitably suffer from the cramped, crowded and cold conditions under which they have to remain. It must be realised that these have a very definite effect upon the standard of night vision, as does the incorrect positioning of the instruments through which a lookout is being kept. A further factor is that men sitting still, as in a D.C.T., will have a slower circulation than men moving about, as for instance on the bridge. This has been proved to affect night vision. Efforts must therefore be made by

the D.C.T. Crew to keep their circulation going by periodical arm movements, deep breathing, etc.

(*c*) *Loss of night vision due to visual fatigue*

Experiments show that this is completely separate from general physical fatigue, and will inevitably occur if anyone concentrates intensely in an attempt to pick up an object for long. It takes the form of periods of partial or complete blackout during which the observer can see little or nothing. This effect occurs if concentrated search is made without any rest for 2–3 minutes, but it can very easily be avoided by the observer taking his eyes away from the binoculars for about 10 seconds at the end of every two minutes' searching. Something important may be missed during this ten-second period, but this is the price that must be paid to avoid the very much longer and more serious blackout period. The Layer and Trainer can arrange to " rest " at different moments so that in fact this routine should not involve any risk of a target being missed owing to the rest period.

(*d*) *Loss of effective vision due to unnecessary re-adjustment of focus, etc.*

There is a tendency on the part of many Director Layers and Trainers when they fail to pick up a target which they know to be visible from the bridge, to re-adjust the focus of their telescopes or binoculars. This tendency is probably part of a general one to distrust instruments and lose confidence in them under conditions of anxiety and stress. The focus of binoculars and telescopes should always be set correctly for the eyes of the man using them, and no alteration to this focus can have anything but a detrimental effect upon the vision of the user. This tendency must therefore be countered by instruction and by building up a man's confidence in the instrument which he uses.

(*e*) *Loss of night adaptation due to relaxed discipline in the D.C.T.*

It is evident that when men have to be closed up for long periods in a D.C.T. it is not possible to maintain the same restrictions upon them, as would be done when closed up in peacetime for the short period of a practice shoot. Thus a certain amount of smoking, and even reading for those members of the crew who do not have to use their night vision, may on occasions be allowed. This introduces a risk of the night vision of Layer, Trainer and Control Officers being affected by the light of a match or the glow from a reading lamp. In order to avoid this possible cause of trouble, Control Officers should consider what modification of procedure may safely be made in the particular tower in question, such as the fitting of a dull electric lighter so that matches are not needed and a small shaded orange light for reading. A small leak of light from this latter would not affect the night vision of those members of the crew who are required to use the telescopes and binoculars, but the light should nevertheless be effectively screened from all except the user.

### Night vision of layers and trainers

103. At the present time the optical test for Layers and Trainers does not include a test of night vision. The cause of delay between bridge and director may therefore occasionally be due to inferior night vision on the part of the Layer and/or Trainer. This can easily be detected by means of a test with an adaptometer.

## SUMMARY OF REMEDIES

104. The following is a summary of the points to which attention should be paid in order to reduce the delay between first sighting by the bridge and the director report of " target ".

### Material

105. (*a*) Adjust the illumination in the interior of the D.C.T. to that prevailing outside by means of a matt white interior finish and the fitting of interior diffused lighting from orange bulbs controlled by a dimmer.

(*b*) Fit suitable dimmers to all instrument illumination, the colour of which should be deep red or orange.

(*c*) Fit efficient dimmer switches in a position accessible to the Layer and Trainer with the off position next to the position of minimum illumination.

(*d*) Improve seating and comfort arrangements generally in any way possible since these have a direct and measurable effect upon the efficiency of night vision.

(*e*) Use anti-mistant on all director optical instruments and Kent clear view screens.

### Men

106. Special instruction should be given to Layers and Trainers on the following points :—

(*i*) The necessity for resting their eyes for ten seconds in every 2 minutes when searching for a target. The taking of ten-second rests by Layer and Trainer at different times.

(*ii*) Dark adaptation. How to obtain and retain it. Use of red light and red goggles. (*See " Handbook on Lookouts and Service Optical Instruments ".*)

(*iii*) Use of dimmers on instruments and graticules.

(*iv*) Bad effect of premature lighting of graticules.

(*v*) Possibility of misting of eyepiece even though nothing appears to be wrong.

(*vi*) Desirability of reading Eversheds and similar instruments from a reasonable distance away to avoid straining the accommodation of the eyes in the " Long-sight " position.

(*vii*) Correct aversion of vision and scanning of binocular fields.

(*viii*) Importance of correct focussing of binoculars and of correct interocular setting, both of which should then be left undisturbed.

(*ix*) Gauging how far and how fast the tower is being trained in the dark. This can only be achieved by constant practice.

(*x*) Importance of adjusting seats to the correct height for using the telescope or binocular most likely to be used at night. An error in height of as little as 1½ inches has a bad effect on night vision through binoculars.

(*xi*) The importance of regular movements and deep breathing to maintain an adequate circulation and so improve night vision.

(*xii*) That the optical instruments provided are good and are efficient and that there is no reason to doubt their efficiency (with consequent panic reactions in an emergency), just because the bridge on occasions can see the target when the D.C.T. cannot.

Further information on many of the above points will be found in the " *Handbook on Lookouts and Service Optical Instruments* ".

107. In addition to the above, arrangements should always be made if possible for a rating other than the Trainer to train the tower whenever any form of Blind training is being employed. This includes the transmission of bearing by Evershed from the Captain's sight. This is most essential both in order that the Trainer's night adaptation may be preserved and also that he may be able to search continuously for the target with his binocular.

## SEARCHLIGHT PRISMS

108. If the enemy uses a searchlight, this must be used as a point of aim since no other part of the hull is likely to be visible.

If the point of aim is raised from the normal one (forecastle deck) to a searchlight it is evident that the M.P.I. will be raised a similar amount ; e.g., if the M.P.I. were 10 feet below the forecastle deck it would be raised to 10 feet below the searchlight, thus missing the main hull.

109. A prism is therefore fitted which the Director Layer can place in front of his telescope when laying on a searchlight. This automatically raises the Director's line of sight through the requisite angle without transmitting extra elevation to the guns, thus the M.P.I. should remain unaltered. The prism is made of neutral-tinted glass so that it also acts as a shade.

110. It is evident that the prism cannot give the correct angle for all heights of searchlight at all ranges, so the following angles have been decided upon as being most suitable :—

(*i*) For all Battleships and Cruisers. Angle of 10 minutes. This is correct for a searchlight 35 feet above the forecastle deck at a range of 4,000 yards.

(*ii*) For all destroyers to which the prisms are fitted the angle is 5 minutes, which is correct for searchlight 15 feet above the level of the forecastle deck at a range of approximately 3,500 yards.

111. At shorter ranges or higher searchlights than the above, the M.P.I. of all salvos will be raised.

Since the height of the searchlight, and the range, may differ considerably from those for which the prism was constructed, the Control Officer must be prepared for some uncertainty in the fall of shot when the prism is used ; for this reason the point of aim should not be shifted to a searchlight unless the normal point of aim is invisible.

When the point of aim is so altered, it must be remembered that a deflection correction may be necessary. The Control Officer must be informed when the point of aim is shifted by the Layer reporting, **" Prisms in "**, or **" Prisms out "**, in order to prepare him for any necessary corrections.

## OPEN SIGHTS

112. It is a common occurrence on dark nights for all sense of the horizontal to be lost, and for this reason open sights are fitted to all directors and to gun sights.

There is a considerable tendency on the part of Layers to employ the telescope on account of its greater comfort, and to use high magnifications with a view to obtaining greater accuracy.

This is a mistake, and Layers should be impressed with the value of the open sight and of the importance of using the lowest power at night. They should not hesitate to fire by open sights if they cannot pick up the target through the telescope.

113. In spite of the above the optical properties of the stabilised systems have been so improved in modern sights that the stabilised telescope is now quite suitable for use at night. This should be remembered for on a really dark night when the Layer may completely lose his sense of the position of the horizon when searching for a target, the stabilised cross-wire will always indicate this within very close limits.

114–118.